2016

Analyzing Managerial Efficiency in Major League Baseball: A Sabermetric Approach

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A Thesis Submitted to

Department of Economics

Skidmore College

In Partial Fulfillment of the Requirement for a B.A. Degree

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May 3rd, 2016

Abstract

Modern statistical analysis has allowed for teams to more accurately measure Major League Baseball player performance. However, other than tracing wins there are few ways to track the performance of on-field managers whose strategies, decisions, and expertise fundamentally influence the outcome of each game. I begin this paper by investigating and critiquing prior empirical analyses that have attempted to quantify the effect of managerial skill on team performance. Using Stochastic Frontier Analysis and data from the 2008-2015 MLB seasons, I expand on previous research by calculating managerial efficiency estimates while including control variables that better objectively measure player performance. I find that the least efficient managers achieve winning percentages that are around 80% of what is possible, given their players' talent level. I then test the foundation from which MLB General Managers pay their managers. By using an ordinary least squares regression, I find that managers are rewarded with contracts based on management experience, but not efficiency. Thus, I provide evidence of an inefficiency in the market for MLB managers. Finally, I explain the implications of this inefficiency and how further research is needed to analyze managerial effectiveness at the in-game level.

I. Introduction

The goal of any manager, in any industry, is to efficiently combine inputs to generate output. When firms in two industries use the same amount of inputs, yet have different output levels, the implication is that one of the firms produced inefficiently (Kahane, 2005). In the case of professional sports, the goal of the firm (team) is no different— to efficiently turn inputs into output. In sports, the inputs are primarily player and managerial talent levels.[1] Output is measured by the number of games won. Quantifying the effect of managers on inputs and outputs in many industries can be difficult due to lack of data. However, the availability of data in professional sports provides scholars with an advantage in studying managerial impact on team performance.

The rise of advanced statistical analysis in Major League Baseball has fundamentally changed the game. Michael Lewis' (2003) *Moneyball: The Art of Winning an Unfair Game,* brought the use of advanced statistics in baseball to the attention of the public masses. Lewis (2003) wrote the story of the 2002 Oakland Athletics and General Manager Billy Beane— and how a small-market team used unconventional player-evaluation methods to field a successful group of players. Beane favored lesser-used statistics like on-base percentage over the more-traditional counts of a player's homeruns and runs-batted-in. His wisdom was simple— the Athletics' payroll could not afford to acquire high-profile players, so they needed to find an inefficiency in the market for players. This inefficiency was on-base percentage. Teams undervalued high on-base percentages, and thus, Beane was able to cheaply acquire players who routinely got on base (and therefore, more likely to score runs), regardless of whether they did so

[1] In the case of this paper, the term "manager" and "head coach" should be considered the same. In Major League Baseball, the on-field leader is called the "manager," while the NFL, NHL, and NBA use the term "head coach."

via hits, walks, or hit-by-pitches. While other teams valued a player's physical makeup— his arm strength, bat speed, and 60-yard dash time, Beane could not care less. As Lewis (2003) writes of Beane's right-hand-man, Paul DePodesta,

> Paul had said the scouts ought to go have a look at a college kid named Kevin Youkilis. Youkilis was a fat third baseman who couldn't run, throw, or field. What was the point of going to see that? (Because, Paul would be able to say three months later, Kevin Youkilis has the second highest on-base percentage in all of professional baseball, after Barry Bonds. To Paul, he'd become Euclis: the Greek god of walks.) (p.19)

Since then, a new field of statistical analysis has enveloped baseball. Coined "sabermetrics," after the Society for American Baseball Research (SABR)— of which many of baseballs' current writers and statisticians are members. The abundance of freely-available data has allowed player analysis to reach depths never reached before. New statistics like wins-above-replacement (WAR), fielding independent pitching (FIP), and weighted on-base average (wOBA) allows teams to better objectively evaluate player performance.

While the sabermetric movement has revolutionized how MLB teams evaluate players, there is still one component of the team that front-offices know little about: the manager. Other than tracing wins, there are few ways to evaluate the performance of the on-field manager. The job of a baseball manager is to make decisions that will benefit the team. More specifically, to help the team win. Baseball managers have to make numerous decisions throughout the course of a game. The manager must comprise the starting batting order, defensive positions, and pitching rotation. Decisions that a manager must make during a game consist of defensive alignment, pitch calling, baserunning tactics, and hitter and pitcher substitution, among others. Successful managers are also required to make sure the right player is in the right situation. For example, certain pitchers are more effective against left-handed hitters, and vice-versa. It is up to the manager to put his players in situations where they are more likely to succeed. Furthermore, skillful managers also know the tendencies of their opponent, and thus create a game plan that will most effectively diminish the opponent's strengths. Lastly, regarding sabermetrics, it is up to the manager to decided how to apply advanced statistical analysis to in-game decision making.

The staging of this paper will occur as follows. Section II provides a brief history of research related to measuring managerial skill in professional sports. Section III describes the econometric model and data that I use in my research. Section IV explains results and implications of managerial performance. Section V offers further areas of possible research. Section VI summarizes and concludes the paper.

II. Literature Review

The history of measuring managerial skill in Major League Baseball can be divided into a few distinct methodologies. The earliest practice, introduced by Porter & Scully (1982), uses Stochastic Frontier Analysis (SFA) to calculate managerial efficiency in MLB via a production function consisting of an output (winning percentage) and inputs (player and managerial performance statistics). This method has been further developed and applied to MLB by Ruggiero, Hadley, & Gustafson (1996) and Smart, Winfree, & Wolf (2008). In a similar fashion, Kahane (2005) uses SFA to measure managerial efficiency in the National Hockey League. Other papers have used a production function (independent of SFA) to investigate the effect of managers on team performance (Kahn, 1993; Singell, 1993; Scully, 1994). Similar to SFA, Data Envelopment Analysis (DEA) has also been used to quantify managerial efficiency in professional sports. Fizel & D'itri (1996) use DEA to measure managerial efficiency in college basketball. Volz (2009) and Lewis, Lock, and Sexton (2009) apply DEA to managers in MLB, while Young Han Lee (2009) uses the same method to calculate managerial efficiency in Korean professional sports. Lastly, Horowitz (1994) and Ruggiero and Hadley (1997) use the Pythagorean Theorem of Baseball method to calculate managerial efficiency in MLB by comparing a team's actual winning percentage to an estimate of maximum possible winning percentage based on runs scored and runs allowed.

1. Stochastic Frontier Analysis (SFA) Literature

Despite the early knowledge that the role of management was crucial to the overall production function of a business, very little was known about the actual impact managers had on output. This was due to the fact that little applicable data existed and the difficulty of separating the outputs and inputs of a traditional business (Porter & Scully, 1982). However, the availability of baseball data and knowledge of outputs (wins) and inputs (player and managerial performance statistics) made measuring managerial efficiency both appealing and feasible.

Porter and Scully (1982) created a Cobb-Douglass production function that compared wins (output) to inputs of player skills, which measure team hitting performance and team pitching performance. Team Slugging percentage (SLG) was used as the hitting input and team strikeout to walk ratio (K/BB%) was used as the pitching input. These statistics were used, over more traditional ones like batting average and pitcher's win-loss record, because they best measure a player's performance independent of factors he cannot control (Porter & Scully, 1982). For example, batting average is not affected by extra-base hits, so power hitters are not accurately represented. And win-loss record is greatly influenced by a team's bullpen, which is beyond the control of the starting pitcher.

From the aforementioned production function, Porter and Scully (1982) calculated managerial efficiency for the years 1961-1980. Results showed that an additional year of management resulted in improved efficiency, at a decreasing rate. Efficiency increased by 0.8% per year, reaching a maximum of 94.4% after 12.5 years (Porter & Scully, 1982). Intuitively, this makes sense. A manager is likely to stay with a team if the team continues to win. Porter and Scully (1982) then went on to find average managerial efficiency by team. While most teams with high winning percentages over the years 1961-1980 also had high managerial efficiencies, the correlation was not perfect. Teams such Boston, Detroit, and Minnesota had lower efficiency scores compared to American League teams with similar winning percentages.[2]

While Porter and Scully's (1982) research was a breakthrough in the evolution of measuring managerial skill, their methodologies had flaws. Ruggiero et al. (1996) used a production function with player *and* managerial inputs to calculate managerial efficiency during the years 1982-1993. In essence, Porter and Scully (1982) defined player skill as a factor of team winning percentage but did not offer any insight into how managers may affect team performance. Results suggest that major league teams can achieve a winning season in two ways. A team can win with superior player talent while having an inefficient manager, such as the 1990 Cincinnati Reds. Or, a team can win with inferior player talent so long as inputs are managed efficiently, as proven by the 1987 Minnesota Twins (Ruggiero et al., 1996).

Smart et al. (2008) uses SFA to calculate managerial efficiency scores in the seasons from 1991-2005.[3] Additionally, they investigate which managerial characteristics have the

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[2] From 1961-1980, the Minnesota Twins had a mean winning percentage of .521 and a mean efficiency score of .849. For contrast, the Kansas City Royals had a mean winning percentage of .526 and a mean efficiency score of .921.

[3] Joe Torre, manager the St. Louis Cardinals and New York Yankees, had highest average efficiency score (.8809 over 14 seasons). Jim Riggleman of the Chicago Cubs and San Diego

greatest impact on efficiency, and what qualities teams are paying their managers for. Total offensive resources (a weighted version of on-base percentage, plus net stolen bases) was used as the offensive/hitting input and team earned run average was used as the defensive/pitching input. The managerial input variables were split into three sections—manager's MLB playing experience, MLB managerial experience, and managerial change. Manager's playing experience included whether the manager played MLB, whether he has been a position player, number of games played, number of years played, and number of teams played for. MLB managerial experience included years managing current team, manager of the year awards, managerial winning percentage, years of MLB managerial experience, and number of MLB teams managed. The managerial change group included dummy variables for first year managing current team, in-year managerial change, and manager's first year in MLB. Interestingly, only the managerial change inputs were significant at a 10% level. The others were insignificant.

Smart et al. (2008) then analyzed the relationship between efficiency and managerial characteristics (measured by the aforementioned qualities). All but the manager's MLB playing experience variables were significant at the 5% level. In other words, more efficient managers often have more managerial experience but do not necessarily need to have MLB playing experience. The only problem with this conclusion is that it is hard to know if managerial experience actually contributes to efficiency, or whether managers who are efficient early in their career simply keep their jobs for a longer period.

Lastly, Smart et al. (2008) found that a manager's salary is not correlated with efficiency but is with experience. Teams reward more experienced managers with higher salaries but aren't

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Padres had the lowest (.7273 over 7 seasons). This can be interpreted as—Joe Torre achieved a winning percentage that was 88% of what was possible, given his players' talent level.

rewarding the most efficiency managers— resulting in an inefficiency in the labor market for MLB managers.

Kahane (2005) uses SFA to calculate managerial efficiency in the NHL. The sample included seasons form 1990-1998. The author finds that more historically successful coaches are able to use their player inputs more efficiently than less successful coaches. Furthermore, a coach that was a former player is, on average, more efficient than a coach who was not a NHL player.

2. Production Function Literature

The production function method looks at the effect of managers on team performance, albeit without providing team-by-team or managerial efficiency scores. Kahn (1993) looked at how player ability is affected by high and low-quality managers, respectively. Team winning percentage is described as a function of player statistics (SLG, K/BB%, stolen bases, fielding percentage, batting average, pitcher's strikeouts, and pitcher's walks) and managerial characteristics (years of managerial experience and lifetime winning percentage). Data was obtained during the seasons from 1969-1987. Results showed that highly skilled managers have a positive influence on player performance more so than less-skilled managers.

Singell (1993) had a production function similar Kahn (1993), but included a greater variety of managerial inputs. Included were variables to account for the manager's experience as a MLB player and management experience in the minor leagues. The sample included seasons from 1945-1965 and results showed that management experience significantly impacted winning percentage and player performance. Certain managers can improve a players slugging percentage by up to 30 points over the course of a season (Singell, 1993).

Scully (1994) further explores of the topic of measuring managerial efficiency via a production function, and how tenure is related to efficiency. Managers use their player's offensive (hitting) and defensive (pitching and fielding) skills to maximize scoring and minimize opponents scoring. Data included team winning percentage, runs scored, and runs allowed. Results show that managerial efficiency is correlated with years of managerial experience. Managerial efficiency is calculated by dividing actual winning percentage by potential winning percentage.[4]

3. Data Envelopment Analysis (DEA) Literature

DEA is a linear programming-based method for evaluating the relative efficiency of turning inputs into output (Lewis et al., 2009). Fizel and D'itri (1996) use DEA to estimate managerial efficiency in NCAA Division 1 basketball from 1984-1991. Winning percentage is described as function of player talent and the strength of the opponent. They find a large gap between the least and most-efficient coaches and that years of managerial experience does not effect efficiency. Results imply that NCAA institutions base their hiring of coaches on winning percentage and not efficiency. The "best" coaches are often mistakenly not hired or fired (Fizel & D'itri, 1996).

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[4] For example, consider the following hypothetical situation. Suppose manager Mike Matheny and the St. Louis Cardinals have an actual winning percentage of .70 in year X, but based on runs scored and runs allowed, the Cardinals have a predicted winning percentage of .55. Assume that this is the greatest difference between actual and predicted winning percentage in MLB during year X. Now suppose that the manager John Farrell and the Boston Red Sox have an actual winning percentage of .60 and a predicted winning percentage of .65. Farrell's managerial efficiency is measured by dividing actual winning percentage (.60) by the sum of predicted winning percentage and the largest residual (.65+.15). His measure of managerial efficiency equals .75. Matheny's efficiency equals one, making him most efficient manager in year X.

Volz (2009) later applies DEA to managerial efficiency in MLB to observe the effect of minority hiring practices. Winning percentage is described as a function of player salary inputs (as opposed to player statistics). Volz (2009) argues that player statistics over the course of a season are likely influenced by the quality of a manager (a high-quality manager may cause a pitcher to have a low ERA). Results show efficiency scores for managers with at least 200 games managed during the season from 1986-2005.[5] Others have applied DEA to measure efficiency in MLB including Lewis et al. (2009).

Young Han Lee (2009) uses DEA to measure managerial efficiency in Korean professional baseball, basketball, and soccer leagues. The sample included the 2007 seasons and results showed that management efficiency is not always correlated with payroll. Richer teams often win because they are capable of consistently acquiring more talented players. However, richer teams occasionally have inefficient management— they underperform (in terms of winning percentage) compared to the talent level of their players. On the other hand, financially inferior teams often display greater efficiency as their expected winning percentage is low given they often have less skilled players.

4. Pythagorean Theorem of Baseball Literature:

Introduced by notable baseball statistician Bill James in 1986, the Pythagorean Theorem of Baseball estimates a team's winning percentage based on runs scored and runs allowed.[6] Horowitz (1994) evaluates managers by comparing a team's predicted winning percentage

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[5] Ron Gardenhire of the Minnesota Twins had the highest efficiency score in the sample (100% over 647 games). Bob Boone of the Kansas City Royals and Cincinnati Reds had the lowest (86% in 815 games).

[6] $win\% = \frac{runs\ scored^2}{runs\ scored^2 + runs\ allowed^2}$

(based on the Pythagorean theorem) to their actual winning percentage. The assumption here is that any difference is attributed to the manager's talent (or lack there of). 18 managers who managed for at least 10 seasons from 1965-1992 are evaluated. Results imply that there is a statistical difference between the best and worst managers, however, even the worst managers are relatively successful.

Ruggiero and Hadley (1997) critiqued the Pythagorean Theorem as way to evaluate MLB managers. The authors suggest that methods used by Horowitz (1994) were inherently flawed. Horowitz (1994) failed to control for player talent. Managers who have more talented players appear better than managers on teams with less talented players. For example, Earl Weaver of the Baltimore Orioles was the highest-ranked manager by Horowitz (1994) while Al Lopez of the Cleveland Indians ranked near the bottom. However, Ruggiero and Hadley (1997) found that Lopez was actually a better manager than Earl Weaver when his team was expected to outscore the opponent by 20%. If the team outscored its opponent by less than 20%, Weaver was the better manager. As mentioned before, managerial skill should be measured at a given level of player talent. If not, a manager may incorrectly appear better than another manager.

III. Methods

While more recent literature has used data envelopment analysis (DEA) to measure managerial skill in MLB, I use Stochastic Frontier Analysis (SFA) in my estimates due to its simplistic nature. SFA's sole requirement is a specified Cobb-Douglass production function. I then use STATA to estimate the function and calculate managerial efficiency scores. Previous studies have included player statistics to control for varying talent level across teams, but (to my knowledge) no studies have included sabermetric statistics.

Stochastic Frontier Analysis (SFA) was developed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). It assumes a Cobb-Douglass production function (expressed in log form) and can be used to assess the effects of managerial skill on team performance in MLB. SFA is used, over the more traditional ordinary least squares (OLS) regression, because of its ability to explain the topmost and bottommost performers in the data by showing how efficiently the inputs are used in generating output. On the other hand, OLS provides an explanation of the "average" behavior that can be applied equally to all data points. SFA can determine the efficiency of MLB managers– or how well managers can lead their team to wins, given their level of playing talent.

The sample for the Stochastic Frontier Analysis consists of all MLB teams that competed in the seasons from 2008-2015. The dependent variable is the proportion of a team's wins to the total number of games played (or, winning percentage). In order to account for the level of playing talent on each team, offensive and defensive team statistics are included as independent variables. FanGraph's position player wins-above-replacement (WAR) statistic (incorporates a player's hitting, baserunning, and fielding ability) is used as the offensive input and Fangraph's pitching WAR statistic is used as the defensive input. Simply put, WAR is a statistic that attempts to summarize a player's total value into a single number. The number compares how many wins, over a season, a player is worth to his team compared to a "replacement-level" player. A "replacement-level" player is defined by FanGraphs as a freely available minor leaguer or a AAAA player from the teams' bench. To give a bit of context, Bryce Harper led MLB in 2015 with a 9.5 position player WAR. Clayton Kershaw had the highest WAR for pitchers at 8.6. On the other extreme, Pablo Sandoval, the Red Sox prized free-agent signing, had a WAR of -2.0 which was the lowest among qualified hitters (Yes, the Red Sox would have been better off starting a minor leaguer at third base). Lastly, a team comprised entirely of replacement-level players (or all players having a WAR equaling zero) is projected to finish the season with 48 wins and 114 losses.

Similar to my paper, the majority of previous literature on measuring managerial skill in professional sports uses team statistics as inputs. The other method, used in far fewer papers, uses team payroll as an independent variable. The argument against the payroll method is that, especially in MLB, a team's payroll may not necessarily reflect the true value of a team. A MLB player does not reach free agency (and thus, does not earn a salary that reflects his true market-value) until his seventh year of MLB service. A player makes the major league minimum of $500,000 during his first three years of service. Salary over the next three years can be an amount agreed-upon between the player and team. If the two sides cannot come to an agreement (which is often the case), the salary is determined through a third-party arbitration hearing. The two sides submit a salary request and the arbitrator decides which is more accurate. The player then receives that salary. So, a team with many young players will have a payroll far below the actual value of the 25 players. Furthermore, the payroll method does not take into account the movement (i.e. trades, signings, and releases) of players during the season. Since only before-season payroll data is available, the impact of a blockbuster mid-season trade is not reflected in the measurement. However, the impact of player movement is recognized by team statistics.

Similar to previous literature, managerial inputs are included in the production function to examine the impact of managers on team winning percentage. The following are included as independent variables (managerial data was obtained from www.baseball-reference.com):

Number of seasons managed (at the beginning of the current season) – a measure of managerial experience. Experience is expected to reflect accumulated expertise in player motivation and development and in adapting to the movement of players (i.e. injuries, trades, releases) (Smart & Wolfe, 2003). It is expected to increase efficiency and thus should have a positive sign.

Career winning percentage (at the beginning of the current season) – another measure of managerial experience. Managers with previous success should continue to have success— based on winning tradition, attitude, and approaches to their current team (Smart & Wolfe, 2003). Again, it is expected to increase efficiency and thus have a positive sign.

Manager-of-the-year award – this variable is equal to 1 if the manager has won a MLB manager of the year award (yearly award given to best manager in both the American and National Leagues-- as voted on by the Baseball Writers Association of America), 0 otherwise. The award indicates previous success and management skills. This variable is expected to have a positive sign.

MLB player – this variable is equal to 1 if the manager has MLB playing experience, 0 otherwise. The hypothesis is that a manager who was formerly a player may have a better understanding of the game than a manager who has not (Kahane, 2005). This variable is expected to have a positive sign.

In-season managerial change – this variable is equal to 1 if there was a mid-season managerial change, 0 otherwise. While managers may change during the season for a variety of reasons (i.e.

illness or change in ownership), most managerial change is a result of poor performance. However, it is unlikely that a interim manager will be a able to improve the team drastically (Smart & Wolfe, 2003). From 2008-2015, there were 26 mid-season managerial changes. This variable is expected to have a negative sign.

National League dummy variable – this variable is equal to 1 if the team plays in the National League, 0 for the American League. It is hypothesized that NL managers, on average, will be less efficient than AL manages because of NL-specific rules. The is no designated hitter in the NL, so managers often pinch-hit for pitchers late in games. NL managers make more decisions, and thus, have more opportunities to appear less efficient. This variable is expected to have a negative sign.

I use STATA to estimate managerial efficiency via the following production function,

$$logwin\% = \beta_0 + \beta_1 loghWAR + \beta_2 logpWAR + \beta_3 logyearsexp + \beta_4 logmanwpct + \alpha_1 award + \alpha_2 player + \alpha_3 change + \alpha_4 NL + \varepsilon \quad (1)$$

where *logwin%* represents the winning percentage expressed in log form, *loghWAR* represents FanGraph's position-player WAR, *logpWAR* represents FanGraph's pitching WAR, *logyearexp* represents years of managerial experience prior to the current season, *logcareerwinpct* represents managerial career winning percentage prior to the current season, *award* is a dummy variable for whether the manager has won a manager-of-the-year award or not, *player* is a dummy variable for whether the manager has MLB playing experience or not, *change* is a dummy variable for whether the team had a in-season managerial change or not, *NL* is a National League dummy variable, and ε is an error term.

IV. Results

Table 1: Descriptive statistics for MLB teams from 2008-2015

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
wpct	240	0.500	0.0679	0.315	0.636
pitchWAR	240	14.33	4.977	2	28
hitWAR	240	19.00	7.603	-1.300	37.50
yearsexp	240	7.203	6.806	0	31.27
manwpct	240	0.460	0.146	0	0.649
MLBplayer	240	0.796	0.404	0	1
NL	240	0.521	0.501	0	1
change	240	0.108	0.311	0	1
award	240	0.421	0.495	0	1

Descriptive statistics for all variables described above appear in Table 1. As noted above, the data set includes season from 2008-2015. During this time period, MLB consisted of 30 teams which results in 240 observations.

Table 2: OLS and Stochastic Frontier Analysis (SFA) estimates of equation 1

Dependent variable: log(winning percentage)

VARIABLES	(1) OLS	(2) SFA
logpwar,	0.183***	0.180***
	(0.0115)	(0.0103)
loghwar	0.159***	0.154***
	(0.00972)	(0.00875)
logyearsexp	0.0113**	0.0108**
	(0.00502)	(0.00472)
logmanwpct	0.0130	0.0133
	(0.0515)	(0.0482)
award	-0.00901	-0.0123
	(0.0107)	(0.0101)
MLBplayer	0.00335	0.000623
	(0.0106)	(0.0101)
NL	-0.0173**	-0.0151*
	(0.00863)	(0.00823)
change	-0.0334**	-0.0453***
	(0.0142)	(0.0140)
Constant	-1.626***	-1.537***
	(0.0602)	(0.0582)
Observations	220	220
R-squared	0.806	
Prob >= chibar2		0.010

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

However, regression analysis only includes 220 observations (Table 2). This is attributed to the logarithmic requirement for variables included in stochastic frontier analysis. The sample includes 20 managers who have no managerial experience, therefore, their *yearsexp* and *careerwinpct* totals are equal to zero. Taking the log of zero is not defined, and thus, a missing value is created. An ordinary least squares regression (Table 2) shows that independent variables *logpWAR* and *loghWAR* are significant at the 1% level. *Logyearsexp*, *change*, and *NL* are significant at the 5% level. Finally, *logmanwpct, award,* and *MLBplayer* are insignificant. The insignificance of the *logmanwpct* is likely attributed to multicollinearity with *logyearsexp***.** Stochastic frontier analysis (SFA) is then used to test for inefficiencies in generating winning percentage from the specified input variables (Table 2). As Smart et al. (2008) offer,

> using a Cobb-Douglass production function allows for the possibility of non-linear effects of offensive and defensive inputs. Since we are estimating a production frontier all data points must be within the frontier. The error terms, therefore, are constrained to be positive and the most efficient manager will have an error term of zero. (p.313)

I can reject the null hypothesis that OLS is the best method to measure this production function because the p-value from the SFA test is 0.01. The coefficient for *logpWAR* is positive and statistically significant at the 1% level, indicating that teams with greater pitching talent tend to win more, all else equal. In other words, a 1% increase in pitching WAR results in a 0.18% increase in winning percentage, on average. Similarly, the coefficient for *loghWAR* is positive and statistically significant at the 1% level, indicating that teams with greater position-player talent tend to win more, all else equal. A 1% increase in position-player WAR increases winning percentage by 0.15%, on average.

Turning to the coaching measures, *logyearsexp* is positive and statistically significant at the 5% level. This implies that more experienced managers tend to win more than less experienced managers. *Logmanwpct, award*, and *MLBplayer* are not statistically significant at any level. As mentioned above, the insignificance of *logmanwpct* is likely due to multicollinearity with the *logyearsexp* variable. Smart et al. (2008) found similar results. Managers who win more tend to stick around for longer periods of time. Intuitively, this makes sense— a manager's retention is decided primarily by his ability to win. This insignificance of *award* implies that managers who have won at least one manager-of-the-year award do not win more than trophy-less managers. The results of *MLBplayer* suggest that playing experience has no affect on managerial quality. Managers who were once players have no advantage in generating wins than managers who never made it to The Show.[7]

The coefficient for *NL* is negative and statistically significant at the 10% level. As hypothesized, the negative coefficient shows that, on average, National League managers are less efficient than their American League counterparts. The coefficient for *change* is negative and statistically significant at the 1% level. As expected, a mid-season managerial change has a negative impact on winning percentage. Teams that change managers mid-season likely do so because of poor performance, and therefore, a lower winning percentage than a team that did not make a change is expected, on average.

Equation 1 was estimated as follows:

$$\begin{aligned} logwin\% = {} & -1.537 + (0.180)loghWAR + (0.154)logpWAR + (0.011)logyearsexp \\ & + (0.013)logmanwpct - (0.012)award + (0.000)MLBplayer \\ & - (0.045)change - (0.015)NL + \varepsilon \end{aligned}$$

Efficiency for each manager is calculated as the ratio of actual winning percentage to the expected winning percentage (obtained from equation 1), given the team's offensive and defensive resources. I calculate the efficiency of each manager with the following:

[7] In other words-- Major League Baseball

$$efficiency = \frac{actual\ win\%}{expected\ win\%\ from\ equation\ (1)} \tag{2}$$

For example, the 2010 Los Angeles Angels had a winning percentage of .494. They had a team position-player WAR of 13.5 and a team pitching WAR of 13.5. Manager Mike Scioscia had 10 years of managerial experience, a .542 career winning percentage in seasons priors to 2010, had won at least one manager-of-the-year award, and was a former MLB player. The Angels had no mid-season managerial change and are part of the American League. By substituting these values into equation (1), it can be seen that the 2010 Angels had an expected winning percentage of .517. Then, an efficiency score can be calculated by dividing the Angels actual winning percentage (.494) by their expected winning percentage (.517). The Angels' efficiency rating for 2010 was .956. This can be interpreted as— the 2010 Angels achieved a winning percentage that was 95.6% of what was possible, given their level of playing talent. After determining managerial efficiency for managers from 2008-2015, I attempt to determine if efficiency is correlated with managerial salaries. In other words, are teams paying their managers based on their efficiency?

Table 3: Average Efficiency for Managers with 4+ Years of Experience during 2008-2015 (greatest to least)

Manager	Team(s)	Years in Sample	Mean_Eff	SD
Matheny	Cardinals	4	.976899	.0048794
Hurdle	Pirates	6	.962354	.0260184
Gonzalez	Marlins, Braves	7	.9616287	.0211575
Showalter	Orioles	5	.9615383	.0233062
Scioscia	Angels	8	.9603903	.023546
Girardi	Yankees	8	.9554107	.0165274
Baker	Reds	6	.9532594	.0088397
Washington	Rangers	6	.9519384	.0111964
LaRussa	Cardinals	4	.9498457	.0054451
Manuel, C.	Phillies	5	.947523	.044792
Bochy	Giants	8	.947315	.0260736
Mattingly	Dodgers	5	.9461148	.0125879
Ventura	White Sox	4	.944706	.0358148
Guillen	White Sox, Marlins	4	.9424755	.0183252
Melvin	Athletics, Diamondbacks	5	.942255	.0448053
Gardenhire	Twins	7	.9420212	.0431298
Maddon	Rays, Cubs	8	.9382597	.035593
Farrell	Blue Jays, Red Sox	5	.9363688	.044357
Francona	Red Sox, Indians	7	.9350508	.0369094
Gibbons	Blue Jays	4	.9329651	.0110666
Leyland	Tigers	6	.9312163	.0385762
Yost	Royals, Brewers	6	.9278911	.0443375
Roenicke	Brewers	4	.9275008	.030093
Black	Padres	7	.9188949	.0585606
Wedge	Indians, Mariners	5	.9131983	.0290577
Collins	Mets	5	.9046489	.0394625
All (n= 220)			.9392692	.035403

Table 3 ranks MLB managers by their average efficiency during years 2008-2015. Mean efficiency scores, standard deviations, years managed in sample, and the teams for which they managed are presented for managers with at least four years of experience. 26 managers were identified. Mike Matheny of the St. Louis Cardinals ranks as the most efficient manager during the time period (0.977) and also is the most consistent (sd = 0.005). Clint Hurdle of the Pittsburg

Pirates is the second most efficient manager during that span (0.962, sd= 0.026). On the other extreme, Terry Collins of the New York Mets ranks as the least efficient manager (0.905), while Bud Black of the Sad Diego Padres is the most inconsistent (sd= 0.059).

Table 4: Managerial efficiency differences between groups above and below the sample mean for managers with 4+ years of experience from 2008-2015

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
0	52	.909239	.0043999	.0317281	.9004059	.9180722
1	91	.9627141	.001204	.0114852	.9603222	.965106
combined	143	.9432686	.002788	.0333397	.9377573	.94878
diff		-.0534751	.0036807		-.0607517	-.0461985

diff = mean(0) - mean(1) t = -14.5283
Ho: diff = 0 degrees of freedom = 141

Ha: diff < 0	Ha: diff != 0	Ha: diff > 0
Pr(T < t) = 0.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 1.0000

Differences in the means of managers listed in Table 3 were tested via t-tests (Table 4). The mean efficiency of the sample (n= 143) was 0.943. There were 91 instances in which a manager achieved an efficiency score above the mean, and 52 when a manager scored below. The mean efficiency of these two groups (0.963, 0.909) is statistically different ($p< 0.001$). In short, while the range of the mean managerial efficiency scores is relatively limited (0.905 to 0.977), there is a statistical difference between the best and worst performers. On the other hand, these results imply that even the worst managers do a credible job.

Examining the Market for MLB Managers

71 managerial salaries from 2008-2015 were obtained from Cot's Baseball Contracts. Due to the fact that MLB is not required to release managerial salary figures, not all salary data

could be found. To observe the relationship between managerial salary, efficiency, and experience, and to get a sense of what MLB teams are basing managerial compensation from, I estimate the following equation:

$$logsalary = \beta_0 + \beta_1 efficieny + \beta_2 yearsexp + \beta_3 manwpct + \alpha_1 award + \alpha_2 MLBplayer + \alpha_3 change + \alpha_4 NL + \varepsilon \quad (3)$$

As is typical in this type of analysis, I estimate equation 3 in terms of the natural log of salary (Krautmen, Von Allmen, & Berri, 2009). It is important to note that while only salaries recorded in the contract's first year should be included in the output data (Krautmen et al. 2009), I include salaries regardless of the contract's year due to the limited availability of data.[8] Similar to player contracts, managerial salaries are guaranteed in spite of whether the manager is still employed by the team.[9] A manager may be fired for a number of reasons, but firings are usually associated with poor on-field performance. Similarly, teams are required to pay player contracts in full whether the player gets injured, sees his performance levels decrease, or is released. Thus, only the salary figure in the contract's first year is included because it best-represents the player's value to the team. A salary figure from any subsequent year may not represent a player's true value because of the risk of injury, decrease in performance, etc. However, it may be appropriate to include managerial salaries from all years because teams often fire managers despite the

[8] For example, if a player signed a 2 year/ $20 million contract prior to the 2015 season, only the $10 million made in 2015 would be included in the data. The $10 million earned in 2016 would be omitted.
[9] In 2016, the Miami Marlins are required to pay $1.4 million to former manager Dan Jennings. Jennings is currently employed with the Washington Nationals as a special advisor to the General Manager (Axisa, 2016).

guaranteed contracts (Huzzard, 2015). Ryne Sandberg with the Phillies and Rick Renteria with the Cubs both signed three-year guaranteed contracts prior to the 2014 season. Neither is still managing. Moreover, the Rays signed then-rookie manager Kevin Cash to a five-year guaranteed contract prior to the 2015 season. The contract is specifically structured to limit the amount of money lost in the event that Cash is fired (Gaines, 2015). Whether the manager is still employed should be a telling sign of if his salary in an indication of his true value.

Table 5: OLS Estimates of Equation 3

VARIABLES	(1) OLS
eff	1.171
	(1.379)
yearsexp	0.0438***
	(0.0108)
manwpct	4.792***
	(1.753)
award	0.177
	(0.125)
MLBplayer	0.301
	(0.193)
NL	-0.392***
	(0.139)
change	0.00556
	(0.164)
Constant	-3.450***
	(1.196)
Observations	70
R-squared	0.640

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

OLS estimates are shown in Table 5. Results were similar to Smart et al. (2008). There is not a significant correlation between salary and efficiency. In other words, MLB teams do not appear to pay managers based on their efficiency. However, teams do reward managers with higher salaries based on their managing experience. Both *yearexp* and *manwpct* were statistically significant. Each additional year of managerial experience increases salary by 4.4%, on average. Furthermore, the National League dummy variable was also significant. American League managers, on average, have a higher salary than National League managers.[10] While my salary data is limited, there appears to be an inefficiency in the MLB manager labor market as teams are paying their managers based on experience, but not efficiency.

For example, it is almost common knowledge amongst baseball writers, analysts, and players that Joe Maddon is a superior manager (Mooney, 2015; Crasnick, 2015). Many believe his eccentric behavior and in-game adjustments enhance his team's chances of winning. His salary reflects this consensus too— the Cubs signed him to a 5 year/ $25 million contract in 2015, making him the highest-paid manager in MLB. However, according to my estimates, Maddon ranks as a slightly below-average manager in terms of efficiency. His average efficiency score of 0.938 from 2008-2015 is below the sample mean on 0.943. On the other hand, Maddon does have nearly 10 years of managing experience, which can partly explain why the Cubs rewarded him with a high salary. In a similar fashion, Dusty Baker was hired as the new Washington Nationals manager in 2016. Despite 20 years of managerial experience, Baker has only one National League Pennant.

This market inefficiency has also resulted in the firing of high-quality managers. Trey Hillman began his managerial career in 2008 with the Kansas City Royals. He was fired shortly into the 2010 season after two-plus years with losing records and now is the bench coach for the

[10] After carefully examining current research journals and online publications, I find no sufficient evidence that supports this claim. It may, simply, be a result of sampling error.

Houston Astros. However, Hillman posted an efficiency score of 0.981 in 2009— good for the highest single-season rating in my sample. The unfortunate truth is that, when teams lose, it is often the managers that are let-go and not the players. A primary reason could be that player contracts are guaranteed while managerial contracts are not. General Managers are under pressure to do *something* when the team underperforms, and it is often the case that the manager is the first one to go.

V. Opportunities for Further Research

While it is not within the reach of this paper, I envision that further research will include a more in-depth analysis of managerial compensation. How much should teams pay their managers and on what basis should they base their valuation from? Due to the fragmented nature of teams publically disclosing managerial salaries, my data is simply too brief to perform such an analysis. The structure of managerial contracts also adds to the difficulty. My data includes salary figures regardless of the year-in-contract. Krautmen et al. (2009) explain that, when using performance variables to predict a player's true value, it is best to only the use salary data from the initial year of the contract. While I have provided information for why it may be appropriate to use all of a contract's yearly salaries when examining the value of the manager, there is sill debate on which method is best. In any case, I have provided evidence of an inefficiency in the market for MLB managers. Teams are basing their managerial compensation off of experience but not efficiency.

It is also beyond the scope of this paper to analyze managerial decisions at the in-game level. The lack of public information on the impact of specific decisions (i.e. pinch-hitting or pitcher substitutions) limits the extent to which managerial performance can be measured.

Though, some informal studies have looked at how Win Probability Added (WPA) can be used to analyze a manager's bullpen use (Vargovick, 2015). In essence, WPA measures a specific events' impact on the likelihood that a team will win.[11] It can be seen that analyzing the WPA of each in-game decision that a manger makes over the course of game and over the course of a season would help understand managerial effectiveness. However, due to time constraints and the exhausting nature of analyzing 162 games for 30 teams over numerous seasons, WPA analysis is beyond the scope of this paper.

As suggested by Smart et al. (2008), further research of the managerial effect should broaden the term "management" to include the general managers, scouts, analysts, and player developers. So much of what goes into fielding a baseball team occurs behind the scenes— in the offices of these baseball operations personnel.[12] While recent advances in statistical analysis allow for teams to measure how many wins a player is worth and how much money they are worth to their teams, there have been few attempts to try to apply this same logic to baseball operations employees. Lewis Pollis, a 2014 Brown University graduate and current Research and Development Analyst for the Philadelphia Phillies, wrote his Senior Thesis in Economics on this subject. By analyzing player transactions (i.e. trades, signings, releases, drafts), Pollis (2014) finds a significant difference in the player-investing ability of general managers. A general manager can be worth eight wins during the course of a season, which equates to a roughly $50 million market value. Considering that the highest paid general manager in 2014 earned $4 million, there is a vast inefficiency in the market for GMs. The next step in this process is to

[11] For example, suppose a batter on a team with a 25% chance of winning strikes out with the bases loaded in the 7th inning. Following the strikeout, the teams chance of winning drops to 19%. The win probability added on this particular play was -6%.

[12] Baseball Operations departments are usually led by the General Manager. They typically consist of scouting, player development, analytics, and minor league operations sub-departments.

determine how much baseball operations employees are worth to their teams and how much a team should spend on front-office candidates.

VI. Conclusion

In this paper, I have explored managerial efficiency across Major League Baseball. In order to do so, OLS regression analysis was performed to determine the effect of managerial characteristics on team winning percentage. This paper uses managerial characteristics that are consistent with previous literature (Smart et al., 2008; Kahane, 2005; Singell, 1993; Kahn, 1993). Similar to (Lewis et al., 2009; Smart et al., 2008; Ruggiero et al., 1996; Singell, 1993; Kahn, 1993; Porter & Scully, 1982), player statistics are included in the regression to control for varying player talent level across teams. Other studies (Volz, 2009; Kahane, 2005) use team payroll instead of player statistics to control for player talent. As noted above, player statistics are a superior control variable because they more accurately represent a team's talent level. Especially in MLB, team payroll may not accurately represent a team's true value because players (especially rookies and arbitration-eligible players) are often paid far below their worth.

This paper differentiates itself from previous literature in its choice of player control variables. Previous studies have used a variety of statistics including batting average, slugging percentage, total offensive resources, earned-run average, strikeout-to-walk ratio, fielding percentage, etc. However, as presented earlier, the influx of sabermetrics in MLB has created a new benchmark for objectively measuring player performance. The WAR statistics combine all aspects of player performance (hitting, fielding, base running, and pitching) into two values that are easily comparable across positions.

In addition, this paper uses Stochastic Frontier Analysis to better understand the impact of managers on team performance. Frontier analysis allows for the measurement of managerial efficiency— or how efficient managers are at turning player talent (measured by team WAR) into wins. Efficiency is obtained by dividing a team's actual winning percentage by their expected winning percentage, based on the frontier analysis. Managerial efficiency scores were provided for managers with at least four years of experience in the sample. A t-test analysis was then performed on the top and bottom performing managers to test for statistical difference. Finally, I investigated the relationship between managerial compensation and performance.

These aforementioned analyses found a number of statistically significant correlations. As expected, greater pitching and position-player talent increases the likelihood of winning. Managers with more experience tend to win more while teams that have mid-season managerial changes tend to win less. National League managers are, on average, less efficient than American League managers because they are forced to make more in-game adjustments. Inconsistent with Singell (1993) and Smart et al. (2008), my analysis did not suggest that MLB playing experience nor manager-of-the-year awards have a positive impact on managerial performance.

In this paper, I believe that I have provided quantitative information that major league teams can use to evaluate the performance of their managers. Furthermore, I have provided evidence of an inefficiency in the market for MLB managers— teams are committing millions of dollars to managers based on experience, but not efficiency. While managerial investments are far below the amount of money spent on players, they are investments nonetheless, so teams should have concrete information for which they can base their investment from.

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